THE CALORIC TESTS*

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By way of introduction the technique and rationale of the Caloric Test procedure, first described in 1942 by Fitzgerald and Hallpike, will be briefly reviewed. Thereafter the interpretation of the results will be discussed and an explanation given of the way in which these results are applied to the diagnosis of the many varieties of vestibular disease commonly encountered at the National Hospital, Queen Square.

In Fig. 1 is shown the Test procedure. The patient lies comfortably

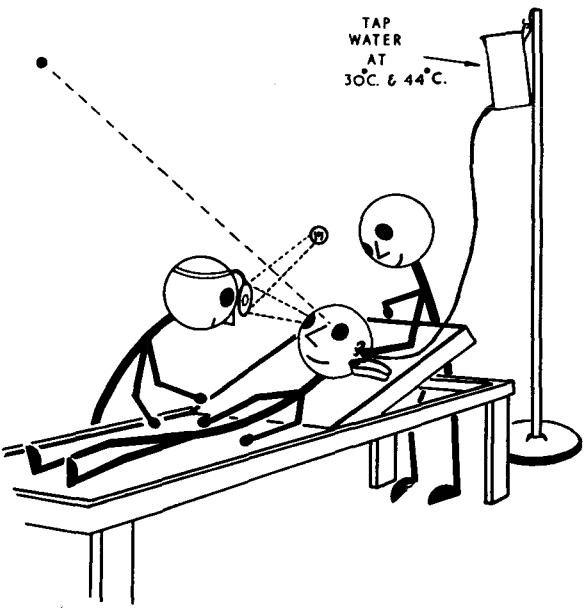


FIG. 1.

upon a couch with his head raised some 30° above the horizontal. This brings the external canal into a position of maximum sensitivity to thermal stimuli. It also provides a most effective means for immobilizing his head, and so making it easy for the examiner to make accurate observations of nystagmus. These observations are carried out with good illumination at a distance of 12 inches or so. The subject fixes his gaze upon a

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small object placed on the ceiling or elsewhere in the straight ahead line of gaze, and the nystagmus observed is, therefore, of the 2nd degree variety. The damping effect of fixation certainly shortens the nystagmus, but it also sharpens the end-point, and so makes it easier to observe. For this reason, abolition of fixation by the use of Frenzel's glasses is best avoided.

The stimulus temperatures are 30° and 44° Centigrade, 7° below and above body temperature. Tap water is used and is allowed to flow into the depths of the meatus for 40 seconds. The flow must be free, without causing discomfort. In practice the quantity varies between 250 and 500 c.c.

Having induced nystagmus in this way, the assessment of its magnitude must next be considered. For this the time period between the application of the stimulus and the end of the visible response is taken. With the cold stimulus this duration is usually about 2 minutes; with the hot stimulus rather shorter, 1 min. 40 secs.

From time to time many questions have been asked about the rationale of this test procedure. What, for instance, determines the choice of stimulus temperatures and duration? Why is the latent period of the nystagmus ignored? To all of these the answer is that the procedure specified is the resultant of the several essential requirements, practical and theoretical, which it is called upon to meet.

Firstly, the tests must be easy for the examiner and easy for the subject.

Secondly, the results must provide a sound and repeatable measure of the sensitivity of the external canal.

Thirdly, they must also be capable of demonstrating that other variety of vestibular derangement, not in itself a function of the sensitivity of the external canal, which we term directional preponderance.

As an example, the question of stimulus temperature and stimulus duration may be taken. At one end of the scale it is necessary to avoid discomfort or deflection of the cupula beyond its physiological limits. Hence, stimuli which are very prolonged, or are far removed from body temperature, cannot be used. Great difficulties also arise at the other end of the scale with the very small stimuli which have been recommended for the estimation of the nystagmus threshold. It is known, for instance, that the thermal changes in the canal develop rather slowly, as do the resultant cupular movements. Hence the nystagmus, which is evoked by such near-threshold stimuli is likely to be complicated by adaptation effects, is faint and flickering in character, is difficult to observe and uncertainly related to the true sensitivity of the canal.

These elementary considerations thus compel the selection of a middle course, a medium deflection of the cupula, using comfortable water temperatures applied for moderate periods.

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A further and common question concerns the preference of duration as the measure of the response, instead of its other attributes, frequency, amplitude or total number of observable beats. The answer is that of the four attributes, two, frequency and amplitude, both vary throughout the course of a nystagmic response. Hence their observation and measurement would require some continuous recording system, optical or electrical, which are excluded from a busy clinic on grounds of convenience. There remain, therefore, the other two attributes, duration and total number of nystagmic beats, either of which can be easily estimated with the naked eye and a stop watch. As it happens, they pursue similar courses; that is to say, the longer the nystagmus in a given subject the greater the number of beats. Thus, it is only necessary to observe the one or the other, but not both. Of the two, duration is the easier, and hence duration is preferred. Now, in relying upon duration alone one obvious quandary might, of course, arise. How, for instance, is it possible to compare a short nystagmus of large amplitude with a long nystagmus of small amplitude? In theory this quandary seems serious. In practice, however, it practically never arises. As will be shown, the interpretation of the results in any given individual depends upon an analysis of the whole pattern of the four responses obtained.

Now it is a matter of experience that in any given individual the largest of the nystagmic responses obtained in this way are also the longest. Hence, for the analysis in any given subject of the pattern of his four responses, it can, after all, be said that duration does provide a reliable measure of their magnitude.

One further point of special interest concerns the repeatability of the test results. Fitzgerald and Hallpike devoted much attention to this point, and in their original communication published in 1942 were able to state that the tests could be repeated in normal subjects without significant variation of the responses.

In 1948 Jongkees published some valuable figures fully confirming these findings, and since then the matter has been studied in some detail by Hood and Pfaltz who found that in rabbits caloric nystagmus could be repeatedly evoked without any fall of the response which is so characteristic with repeated rotational nystagmus, a fall which it is usual to attribute to a process called habituation. Whatever its cause, this variation of rotational nystagmus with repeated stimuli introduces a serious difficulty in its quantitative evaluation. The fact that it should occur with rotational but not with caloric stimuli raises points of great practical and theoretical interest and deserves the very close attention of all interested in the subject.

It is necessary next to consider the recording and interpretation of the test results. Before doing so, however, attention must be directed to certain small but very practical points upon which the smooth and easy

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conduct of the tests is greatly dependent. These are illustrated in Fig. 2.

Firstly, the adjustment of the water temperatures. Ideally, water at the correct temperature should be available from thermostatically regulated tanks. In practice, however, the douche can must be filled afresh for each stimulus. Water from cold and hot taps is mixed in the douche can, and it is found that the temperature adjustment is greatly

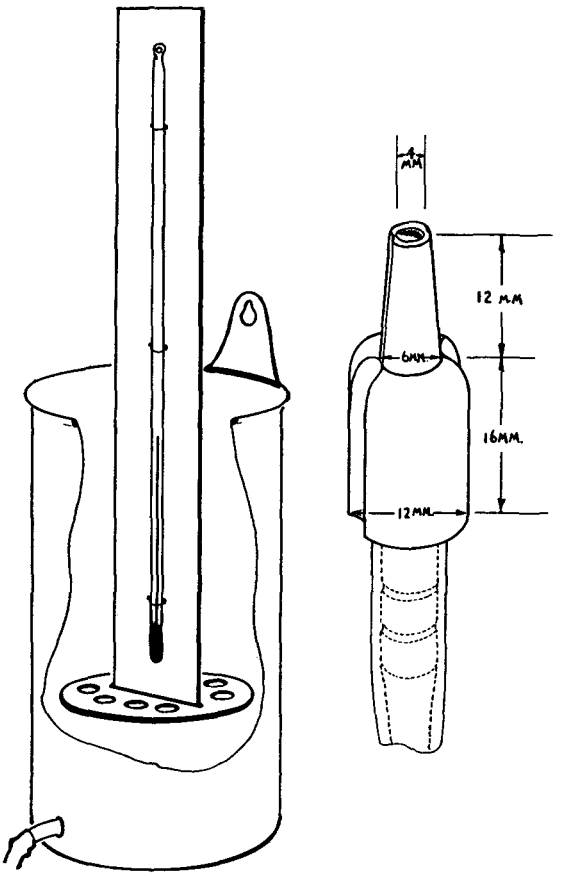


FIG. 2.

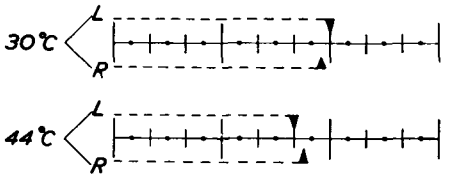
facilitated by the use of a perforated plunger, to which is attached an easily-read thermometer.

Another point of importance is the design of the nozzle through which the water is delivered to the ear. This is constructed of ebonite or plastic material. The terminal part which enters the ear is some 10 mm. in length with a rounded extremity and a flange at its base to prevent it passing too deeply. The flange is partly cut away to permit the free return of the water. The internal diameter of the nozzle, 4 mm., is found sufficient to

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permit the passage of the required amount of water with the douche can itself at a convenient height of 6 feet. With this nozzle very little care or skill are required, either to insert it or to maintain it in position. This greatly eases the task of the examiner.

The recording of the results will next be considered. In Fig. 3 is shown



NORMAL.

FIG. 3.

the diagram used and the results obtained in an average normal subject. The continuous lines represent time, 3 minutes divided into 10 second intervals. Above are shown the two responses, Left and Right to the cold stimulus 30° C. Below are the two responses Left and Right to the hot stimulus, 44° C. It is convenient for reference to number these reactions 1-4 from above downwards. Responses 1 and 4 consist of nystagmus to the right. Responses 2 and 3 consist of nystagmus to the left.

The commonest variety of abnormality is that shown in Fig. 4, a one-

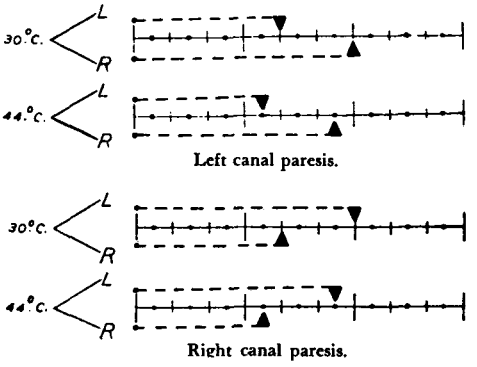


FIG. 4.

sided reduction of sensitivity; as termed by Fitzgerald and Hallpike, a canal paresis. Above, with a left paresis, reactions 1 and 3 are reduced with respect to reactions 2 and 4. Below, with a right paresis, the opposite is the case. The paresis may, of course, be of any degree up to a complete unilateral absence of response.

Now if the only purpose of the tests was to reveal a canal paresis, it might well be asked whether it is necessary to use hot as well as cold stimuli since the information from the former will merely reduplicate that from the latter.

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The answer is that the tests are designed to reveal not only changes of canal sensitivity, but also that certain other derangement, directional preponderance. This, though apparently unrelated to changes in canal sensitivity carried a vital significance in the diagnosis of vestibular disease.

In Fig. 5 is shown what is meant by directional preponderance of the caloric responses. Above is shown directional preponderance to the left. Responses 2 and 3 are enhanced with respect to responses 1 and 4. Below, with directional preponderance to the right, the reverse is the case.

Directional preponderance of this kind may be caused by lesions in various parts of the vestibular system, from the cerebral hemisphere to

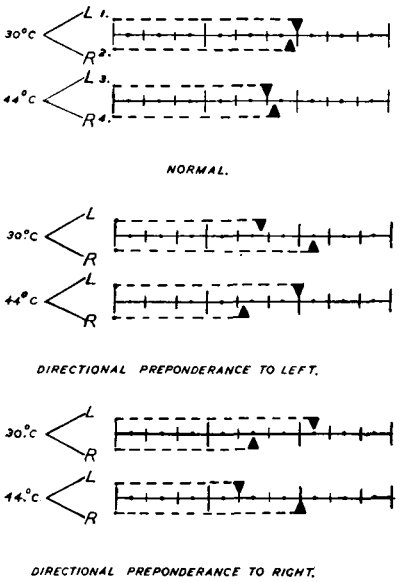


FIG. 5.

the labyrinths themselves. For instance, it is now known that lesions of the posterior part of the temporal lobe bring about such a directional preponderance to the side of the lesion, a physical sign which is found very useful in dealing with the many subjects with supra-tentorial lesions seen at Queen Square. Most commonly, however, it is encountered with unilateral labyrinthine lesions and the physiological basis for this fact still provides an important problem.

First of all, it seems justifiable to assume that it is quite unconnected with changes of canal sensitivity. Thus, with directional preponderance to the right the sensitivity of the right canal, though reduced with the cold stimulus, is enhanced with the hot. It has, therefore, been argued that directional preponderance to the opposite side, occurring in association

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with a unilateral labyrinthine lesion, is due to a lesion not of the canals, but of some other sense organ or organs which exercise a modifying influence upon nystagmus which takes place in a particular direction.

Put in its simplest form, the argument goes something like this. Destruction of the right labyrinth causes spontaneous nystagmus to the left. This is due to the abolition of the tonic action of certain or all of the sense organs of the right labyrinth, and the unbalanced action of the corresponding organs of the left labyrinth.

Now, directional preponderance of caloric nystagmus to the left is almost certainly a partial form of spontaneous nystagmus to the left and it can, therefore, be attributed to a partial lesion of the sense organs of the right labyrinth. The question is, which sense organs?

Now, as will be shown later, if a large number of cases be taken of Ménière's disease affecting the sense organs of the right labyrinth, a lesion of the external canal, as shown by the occurrence of a canal paresis, is very frequently present without any directional preponderance. Conversely, directional preponderance quite often occurs without any evidence of a canal lesion. On both counts, therefore, it seems reasonable to suppose that directional preponderance to the sound side in cases of unilateral labyrinthine disease is due to a partial lesion not of the canal organs, but of one or other or both of the remaining sense organs, the otolith organs of the saccule or utricle. It goes, of course, without saying that full experimental and other evidence for this suggestion are lacking. Nevertheless, it seems essential to take as a starting point, the clinical facts as they are known. Namely, that directional preponderance of caloric nystagmus to the sound side does occur as the sole manifestation of a unilateral labyrinthine lesion. Since it cannot be satisfactorily explained in terms of a canal lesion, it is necessary to have recourse to this otolith theory, which still provides our basis of approach to the subject. Now of the two otolith organs, it is known that the saccule, at any rate in certain animal forms, plays the part of a vibration receptor. The function of the utricle, however, is purely equilibrial, and for this reason Cawthorne, Fitzgerald and Hallpike have emphasized the possible part played by utricular lesions in bringing about the phenomenon of directional preponderance.

Thus, when directional preponderance is encountered to the right or left, occurring as it often seems to do as the result of a unilateral labyrinthine lesion, it is attributed as a matter of convention, at once serviceable and reasonable, to a lesion of the opposite utricle.

Reverting, therefore, to the normal pattern of the responses shown in Fig. 3, it can be seen that from this there are two primary types of deviation. Canal paresis, due to a lesion of one or other external canal, and directional preponderance due to a lesion of one or other utricle. In any organic disorder of the labyrinth, vestibular nerve and perhaps, too, of its central pathways, these deviations may occur singly or in combination.

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The possibilities thus created are shown in Fig. 6. In this diagram will be seen again the normal pattern of the responses, with the four primary abnormalities which may occur as a result of any unilateral affection of the labyrinth or vestibular nerve.

Left or right canal lesions.
Left or right utricular lesions.

Lesions of the left canal or left utricle usually occur separately; not infrequently they are combined. Such uncrossed combinations are common

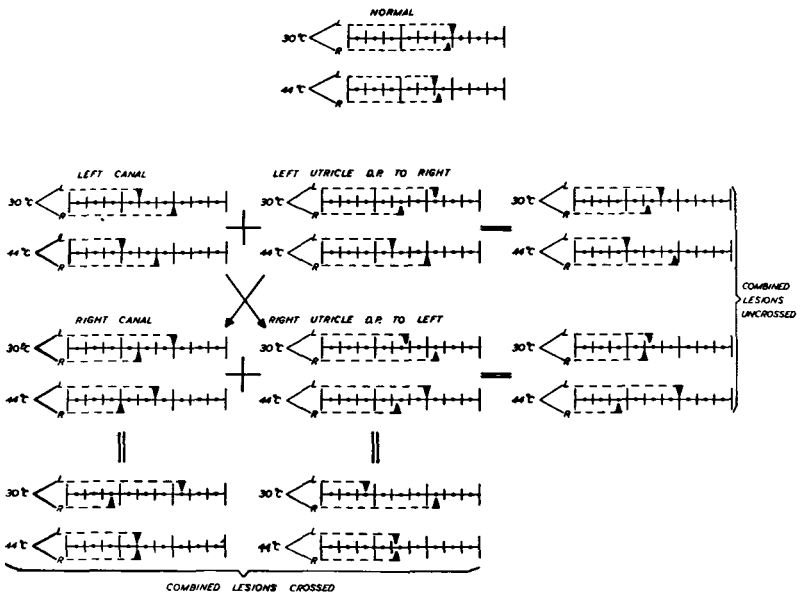


FIG. 6.

and are shown on the right of the figure. They result from algebraic summation of the primary abnormalities.

In cases of bilateral vestibular disease, crossed combinations are also sometimes encountered, and are shown at the bottom of the Figure. They are rare. They arise in the same way from algebraic summations of the two primary abnormalities.

To summarize these results, the Figure shows the normal pattern and the four primary abnormalities. It shows, in addition, the four possible combinations. Firstly, the uncrossed combinations which are comparatively common. Secondly, the crossed combinations which are comparatively rare.

It is necessary next to consider the application of these test methods and their results to the diagnostic problems of vestibular disease, and for this is needed a knowledge of the extent to which these various deviations from the normal occur in normal subjects.

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The Caloric Tests

It will be seen that from the normal test pattern (Fig. 3), four characteristics can be extracted. Firstly, total sensitivity. This is the sum of the reactions 1, 2, 3 and 4. Secondly, the cold/hot sensitivity differences. This is the sum of the reactions 1 and 2, minus the sum of reactions 3 and 4. Thirdly, the left/right sensitivity differences. This is the sum of reactions 1 and 3, minus the sum of reactions 2 and 4. Fourthly, directional preponderance. This is the sum of reactions 1 and 4 which consist

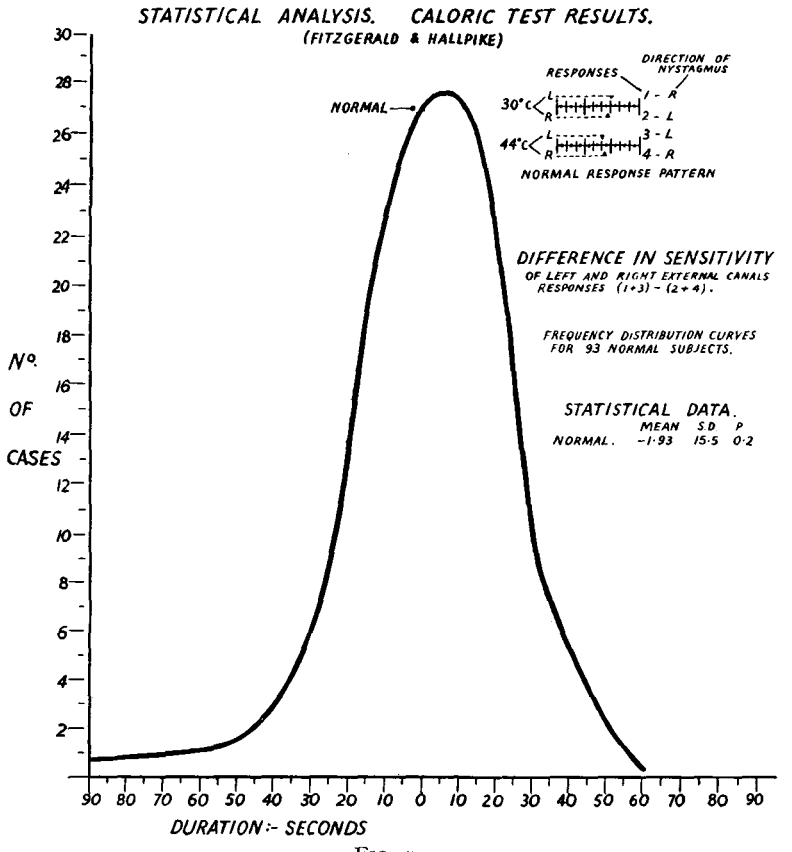


FIG. 7.

of nystagmus to the right, minus the sum of reactions 2 and 3, which consist of nystagmus to the left.

In 1950 Hallpike, Harrison and Slater published the results of a detailed statistical analysis of the caloric test results in 93 normal subjects in respect of these four characteristics. It is proposed here to refer only to the findings in respect of left/right sensitivity difference which corresponds, of course, to our canal paresis and directional preponderance.

In Fig. 7 are shown the results for left/right sensitivity difference.

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The curve has a form which comes very near to that of a Gaussian frequency distribution curve. The mean value is substantially zero and the standard deviation has the reasonably low value of 15 secs.

In Fig. 8 are shown the results for directional preponderance. The curve has a true Gaussian form with a mean value of zero. The standard deviation has again the reasonably low value of 15 secs.

Similar statistical analyses have been carried out by Petermann of Zurich, and Thomsen of Copenhagen. Their results differ very little from those of Hallpike, Harrison and Slater, and the data in general provide a very satisfactory basis for the interpretation of the caloric test findings in abnormal subjects. It is right, however, to add that the diagnostic

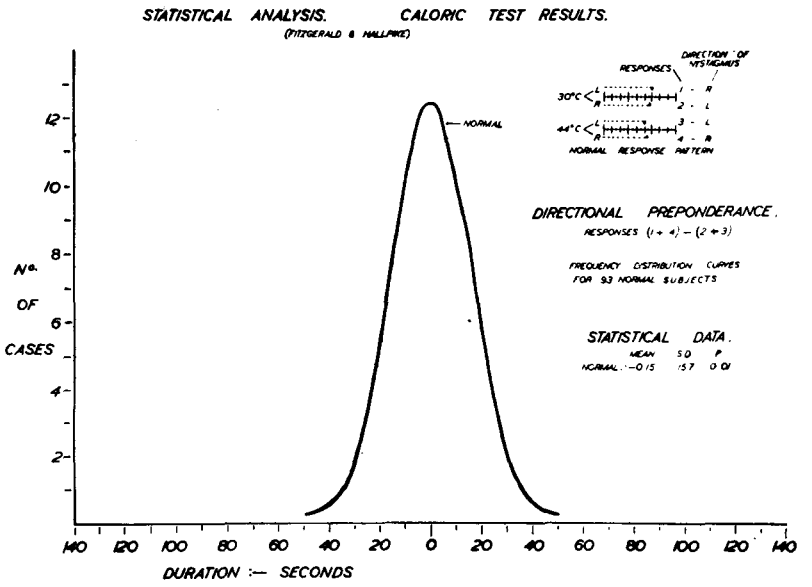


FIG. 8.

significance thus attached to these findings has more than a statistical basis. It is founded, in addition, upon the clinical experience that when these abnormalities, canal paresis and directional preponderance do occur, they are nearly always related in a physiologically appropriate manner to some vestibular lesion, for the existence of which there is other clinical or post mortem evidence.

In the final part of this communication an endeavour will be made to explain the uses of the caloric test results in the practical business of diagnostic otoneurology as practised at Queen Square.

Discussion will be limited to the four following varieties of vestibular disease which are commonly encountered.

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1. Ménière's disease.
2. Vestibular neuronitis.
3. Tumours of, or affecting the VIIIth nerve.
4. Lesions of the temporal lobes.

1. *Ménière's Disease.* The diagnosis of Ménière's disease or endolymphatic hydrops, is dependent, as is well known, upon a highly characteristic set of symptoms: Deafness, tinnitus, distortion of hearing with paroxysmal attacks of vertigo accompanied by nausea and vomiting. The hearing of the affected labyrinth is always reduced, and full loudness recruitment is always present. The caloric tests, carried out in several hundred subjects, give the results shown in Table I.

TABLE I.

Directional preponderance to the opposite side	21%
Canal paresis	49%
Directional preponderance plus canal paresis	18%
Normal	12%

It is of interest to note that if the caloric tests are repeated in any given subject throughout the course of the disorder, the pattern will not infrequently be found to vary. Thus, on one occasion directional preponderance alone may be present. At other times, canal paresis. At other times the two may be combined.

In spite of such variations, however, the results, interpreted according to the principles described, are always indicative of a lesion of the affected labyrinth.

2. *Vestibular neuronitis.* This is a common and important disorder, the clinical features of which were first described by Dix and Hallpike in 1949, and again in greater detail in 1952. It affects adults, and vertigo, often accompanied by nausea and vomiting, constitutes its salient clinical feature. By contrast, however, cochlear symptoms and signs are conspicuously absent. The condition is frequently associated with evidence of infection, either from foci in the nose and throat or elsewhere. Caloric tests always reveal abnormalities, frequently severe and very often bilateral.

In Table II are shown the caloric test results in 100 consecutive cases:

TABLE II.

Directional preponderance	8%
Canal paresis	76%
Directional preponderance plus canal paresis	16%
Normal	Nil

It is important to add that in nearly half of these cases bilateral abnormalities of the responses were present.

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3. *Tumours of or affecting the VIIIth nerve.* These tumours in the later stages of their development, press on the cerebellum and brain stem and cause the various neurological features, ataxia, nystagmus and trigeminal signs with which we are all familiar. Their surgical removal at this stage is difficult and attended by much post-operative morbidity.

In their early stages, however, the removal of these tumours can be remarkably easy, as witnessed in several cases seen with Mr. Wylie McKissock, of the Neurological Department of the National Hospital.

The neurological effects of such small tumours are likely to be confined to the VIIIth nerve, and their successful diagnosis is thus very much dependent upon the results of the tests of cochlear and vestibular function. Some deafness is always present, although it may be surprisingly small in amount. It is nearly always of the perceptive type and as shown by Dix, Hallpike and Hood in 1948, it is distinguished from the perceptive deafness of Ménière's disease by the fact that loudness recruitment, so prominent a feature of that disorder, is characteristically incomplete or absent.

In the investigation of vestibular function, the caloric tests are of outstanding importance. In advanced cases the caloric responses are always absent or severely reduced. With early cases, however, one or other of the less severe abnormalities, already described, may be present, for instance, directional preponderance alone, a canal paresis, or a combination of the two. These abnormalities must be carefully looked for, and if correctly interpreted are of high significance.

4. *Temporal lobe lesions.* In the final part of this communication consideration will be given to the otoneurological diagnosis of supratentorial lesions, in particular of the temporal lobes. As is known, Dusser de Barenne and De Kleyn in 1923 showed that removal of one cerebral hemisphere in the rabbit leads to a directional preponderance of induced vestibular nystagmus to the side of the absent hemisphere.

This finding has been confirmed and extended as the result of observations carried out at Queen Square in the course of the last ten years upon an extensive series of subjects suffering from a variety of unilateral cerebral lesions.

First of all, it has been possible to examine a large number of subjects suffering from infantile hemiplegia. In many of these the affected hemisphere was removed at operation and proven to be the site of gross organic disease. In these cases the caloric responses have always shown a marked directional preponderance to the side of the lesion, thus confirming the broad findings of de Barenne and De Kleyn.

While this certainly makes it clear that severe unilateral cerebral damage is constantly accompanied by directional preponderance of caloric nystagmus to the side of the lesion, it does not make it possible to localize the particular area of brain damage which is responsible for

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this physical sign. This question, however, has been answered by the findings in a series of other cases with localized lesions of one hemisphere. Thus, in Fig. 9 is seen a number of such lesions, some in the anterior part of the temporal lobe, some in the frontal lobe and some in the upper part of the parietal lobe.

Now, with none of these lesions was there any directional preponderance of caloric nystagmus, and this leads to the conclusion that this disturbance must arise from damage of some part of the cortex other than those affected by these lesions; for instance, the posterior part of the parieto-temporal region. This suggestion has been confirmed by a series of findings in a number of cases with localized cerebral lesions which did

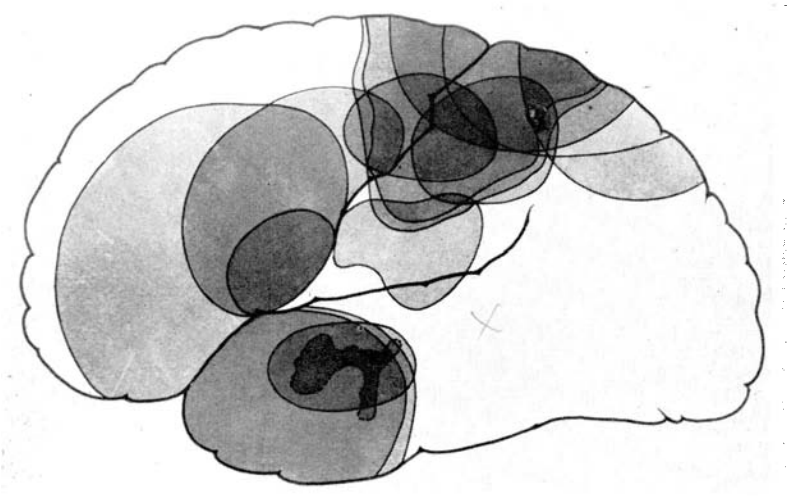


FIG. 9.

exhibit directional preponderance of caloric nystagmus. These findings are shown in Fig. 10. Here is seen the distribution of a number of such lesions, eight in all, and it will be noted that they are confined in a very striking manner to the posterior part of the temporal lobe. Thus the caloric tests are of great value also in the diagnosis of cerebral lesions. In fact, the finding of a directional preponderance may be the only physical sign of a lesion of the posterior part of the temporal lobe.

It will therefore be seen that in all of these four conditions, Ménière's disease of the labyrinth, vestibular neuronitis, tumours affecting the VIIIth nerve and lesions of the temporal lobe, all of great clinical importance though of widely differing pathology, a salient feature of the oto-neurological findings, is some abnormality or other of the caloric responses. While this may often take the form of a reduction of sensitivity of one or both external canals, a so-called canal paresis, this abnormality may also

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occur in association with a directional preponderance. Alternatively, this latter phenomenon may occur alone. Thus, if full diagnostic use is to be made of the caloric test results, then it is essential that they should be interpreted according to the principles which we have described.

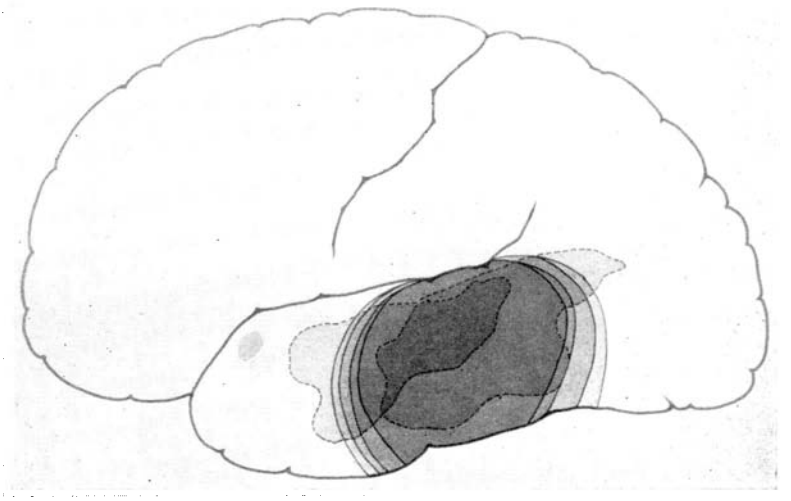


FIG. 10.

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